| (51) International Patent Classification 6 : F02M 35/104, 25/07, F02B 29/00, 37/00, F02D 21/08 | **A1** | (11) International Publication Number: **WO 99/40312** |
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| | | (43) International Publication Date: 12 August 1999 (12.08.99) |

(54) Title: COMBUSTION ENGINE ARRANGEMENT
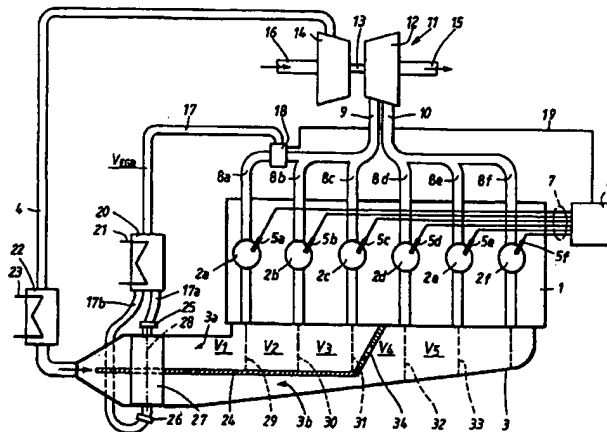
(57) Abstract

The invention relates to a system for a combustion engine (1) comprising at least two cylinders (2a–2f), an inlet (3) for the provision of air, an outlet (9, 10) for the emission of exhaust gases, an additional pipe (17) for the recirculating of exhaust gases from at least one cylinder (2a) in the engine (1) to the said inlet (3) for the reduction of harmful emissions from the engine (1), and at least one energy–recovery unit (12) comprising a device (12) for recovering energy from the exhaust gases and also a device (14) for compressing air for the said inlet (3). The invention is characterized in that the said inlet (3) is designed with a volume, calculated from the connection (25, 26) of the said pipe (17) to the inlet (3) and up to the inlet port of the respective cylinders (2a–2f), which is so dimensioned that the exhaust gases which are recirculated from the said cylinder (2a) are divided principally equally between the respective cylinders (2a–2f) of the engine (1). The invention provides an improved system particularly for a diesel engine with an EGR system, by which means an even distribution of the recirculated EGR gases to the respective cylinder (2a–2f) is obtained.

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Combustion engine arrangement

TECHNICAL FIELD

5    This invention relates to a system for a combustion engine, in accordance with the preamble to the following claim 1. The invention is in particular intended for the reduction of harmful emissions from a diesel engine which is fitted with a system for recirculating the exhaust gases to the inlet of the engine, what is known as an EGR (exhaust gas recirculation) system.

10

BACKGROUND ART

For goods vehicles powered by diesel engines there is a general desire to reduce, to the greatest possible extent, the emission of harmful pollutants in the exhaust gases from the engine. These emissions consist mainly of nitrous oxide pollutants ($NO_x$),
15   carbon monoxide (CO), hydrocarbons (HC) and soot. A number of different measures can be taken in order to reduce these emissions. For example, it is already known that the design of the combustion chamber in the cylinders of the engine and the timing of injecting fuel into the engine can be adapted to minimize the emissions. In those cases where the diesel engine is fitted with a turbo unit, the
20   emission of $NO_x$ pollutants can also be reduced by cooling the air fed into the engine (what is known as intercooling.)

For engines running on petrol, cleaning of the exhaust gases is normally carried out using an exhaust catalyser as part of the exhaust system. Because a diesel engine is run with an excess of air, the normal type of three-way catalyser cannot be used
25   to reduce the $NO_x$ pollutants from diesel engines.

As a result of environmental requirements and expected future legislation, it has become increasingly desirable to reduce the emission of in particular $NO_x$ pollutants
30   from diesel engines. An already known way of achieving this is to delay the combustion in the cylinders. However, a too-late a combustion reduces the efficiency of the engine in question. Another way of reducing the emissions of $NO_x$ pollutants from a diesel engine is to provide it with what is known as an EGR (exhaust gas recirculation) system by which a certain amount of the exhaust gases
35   can b  recirculated from the exhaust pipe of the engine to the inlet of the engine.

The formation of $NO_x$ pollutants in a diesel engine is mainly exponentially proportional to the local maximum temperature in the combustion chamber, and by using an EGR system the temperature during combustion can be reduced by dilution with the exhaust gases, which in turn leads to a reduced formation of $NO_x$.

A diesel engine can be designed with an EGR system by means of a special pipe being connected between the exhaust pipe of the engine and a point in connection with the engine's fresh air intake. Along this pipe there is fitted a controllable valve, which in turn is connected to a control unit. This control unit is arranged so that, depending upon the current operation of the engine, in particular as regards its rotational speed and load, it determines a suitable degree of opening for the valve. The setting of the valve in turn controls the amount of EGR gases that is recirculated to the inlet of the engine. If the pressure of the EGR gases at the exhaust side of the engine is higher than the pressure at the intake side this creates a driving force which urges the EGR gases to the inlet side of the engine.

Where a diesel engine with an EGR system is used together with a turbo system and an intercooler, it is not appropriate to recirculate the EGR gases to a point on the inlet side of the engine which is upstream of the turbo system's compressor and intercooler, as this can lead to unwanted fouling of the intercooler and too high temperatures in the compressor. For this reason such an EGR system is preferably arranged so that the EGR gases are fed from a point on the exhaust side which is upstream of the turbo unit's turbine and to a point on the inlet side which is downstream of the intercooler.

Where an EGR system is used in the way described above, a problem arises however, in that in most parts of the system there is a higher pressure from the turbo unit's compressor (that is at the point in the engine's intake pipe where the incoming fresh air is fed to the engine) than at the exhaust outlet of the engine. This means in turn that there is no driving force from the exhaust side of the engine to the intake side. For this reason no flow of EGR gases can be recirculated to the engine. It is already known per se that this problem can be solved by designing the turbo unit with variable turbine geometry. In this way a sufficiently high pressure can be built up on the exhaust side of the engine. This solution has, however, the disadvantage that it results in a deterioration of the engine's heat balance which in turn makes the engine less efficient.

There is therefore a need for an engine system comprising an EGR system and an exhaust gas system with a turbo unit which provides a sufficient driving force for the EGR gases and which gives a minimal deterioration of the heat balance. This can be provided by the EGR system being arranged in such a way that the EGR gases

5    are taken from only one cylinder in the engine. By means of such a system the back-pressure can be increased for only one cylinder (whereby there is only a relatively small deterioration of the heat balance) so that a sufficient driving force is obtained. This can in turn be achieved by using a shunt valve which also works as a metering valve controlling the amount of EGR gases required at that particular point

10   of the system. This also means that the exhaust gases from this one cylinder which are not directed to the EGR flow are directed to the turbine in the conventional way together with the exhaust gases from the other cylinders.

A problem that can arise in connection with a system which used EGR gases from

15   only one cylinder results from the fact that the exhaust gases are emitted from this one cylinder in pulses which gives a correspondingly pulsating flow of EGR gases to the inlet side. This in turn means that the EGR gases are not distributed evenly to the cylinders at the inlet side of the engine, but that there are different levels of EGR gases to the different cylinders. If there is too great a range in the amount of EGR

20   gases fed to the different cylinders, there will be an insufficient reduction of the formation of $NO_x$ caused by combustion in the cylinders with low EGR gas content. In addition there is a danger of a considerable (and unwanted) build-up of smoke and soot in the exhaust gases from the cylinders with high EGR content.

25   DISCLOSURE OF INVENTION

The object of this invention is to provide an improved system for reducing harmful emissions from a combustion engine, intended in particular for a diesel engine with an EGR system and an exhaust system with a turbo unit, which in particular provides a sufficient driving force for the EGR gases and an even distribution of the

30   EGR gases between the different engine cylinders. This object is achieved by means of a system with the characteristics described in claim 1 below.

The system according to the invention is intended for a combustion engine which comprises at least two cylinders, an inlet for the supply of air, an outlet for the output

35   of  xhaust gases, an additional pipe for the recirculating of exhaust gases from at

least one cylinder in the engine to the said inlet for the reduction of harmful emissions from the engine and at least one energy-recovery unit comprising a device for recovering energy from the exhaust gases and also a device for compressing air for the said inlet. The invention is characterized by the said inlet

5      being designed with a volume calculated from the connection of the said pipe to the inlet and up to the inlet port of the respective cylinder which is so dimensioned that the exhaust gases which are recirculated from the said cylinder are distributed principally equally between the different cylinders of the engine. By means of this even distribution the conditions are favourable for an optimal reduction of NO$_x$

10     emissions from the engine.

The invention can, for example, be used with a six-cylinder diesel engine and according to a preferred embodiment of the invention the said inlet can then consist. of an inlet manifold which is divided into two halves or partial volumes for three

15     cylinders each. In addition there is preferably recirculation of EGR gases from only one engine cylinder, which means that the back-pressure is only increased for that cylinder. This results in turn in a minimal deterioration of the gas exchange work of the engine.

20     Preferred embodiments of the invention are described in the following dependent claims.

BRIEF DESCRIPTION OF DRAWINGS

In the following the invention will be described in greater detail with reference to an

25     example of a preferred embodiment and the attached figure, which shows in diagrammatic form a system according to this invention.

PREFERRED EMBODIMENT

Figure 1 shows diagrammatically a system according to this invention which in

30     particular can be used for a combustion engine 1 of the diesel type. According to a preferred embodiment the diesel engine 1 is intended to be used in a goods vehicle and comprises six cylinders 2a, 2b, 2c, 2d, 2e and 2f. However, the invention is not restricted to a certain number of cylinders, a certain cylinder configuration or a certain type of fuel.

In a way which is already known per se the engine 1 is designed with an inlet manifold 3 to which air is fed from the atmosphere via an inlet pipe 4. As will be described in detail below, the air supplied is distributed between the different cylinders 2a-2f. In addition fuel is supplied to the cylinders 2a-2f via a corresponding number of fuel injection devices 5a, 5b, 5c, 5d, 5e and 5f, which are arranged in connection to the respective cylinders 2a-2f and which are each connected to a central control unit 6 via electrical connections 7. The control unit 6, which is preferably computer-based, is arranged in a known way to control the injection devices 5a-5f so that at any moment a suitable fuel/air mixture is provided for the engine 1, that is to say so that the mixture provided at any time is adjusted to suit the current operating conditions. The injection device can also be of conventional mechanical type.

The cylinders 2a-2f are provided with an exhaust gas outlet 8a, 8b, 8c, 8d, 8e and 8f, which together form a branched exhaust gas pipe. The three exhaust gas outlets 8a-8c which lead out from the three first cylinders 2a-2c are connected to a first exhaust gas pipe 9, while the three exhaust gas outlets 8d-8f which lead out from the fourth, fifth and sixth cylinders 2d-2f are connected to a second exhaust gas pipe 10. The first exhaust gas pipe 9 and the second exhaust gas pipe 10 pass through a turbo unit 11 which is principally conventional. Thus the turbo unit 11 comprises a device for recovering energy from the exhaust gases in the form of a turbine 12 which is rotated by the exhaust gases which flow through the two exhaust gas pipes 9, 10. The exhaust gases which have passed through the turbine 12 are then led out into the atmosphere via an outlet 15 which in turn is preferably fitted with a (not shown) silencer.

Instead of a conventional turbo unit, what is known as a Comprex charger can in principle, be used as an alternative device for recovering energy from the exhaust gases and supplying compressed air to the inlet of the engine.

As an alternative to the embodiment shown in the figure, which is designed so that the exhaust gas outlets 9, 10, are arranged in two groups with two pipes leading to the turbine 12 (what is known as twin inlet), the exhaust gas outlets 9, 10 can instead join into a single exhaust gas pipe (what is known as single inlet).

According to another alternative to the embodiment shown in the figure, the exhaust gas outlet can be divided into two or more groups by which the exhaust gases are fed to a corresponding number of separate turbo units.

5    The turbine 12 is arranged on an axle 13 on which a compressor is also arranged. The energy which is recovered from the flow of exhaust gas by the turbine 12 is transferred in this way to the compressor 14 which is arranged to compress air flowing in via an inlet 16 and to feed this air to the inlet pipe 4. By this means, in a known way an increased amount of fuel can be delivered to the engine 1, whereby
10   its power can be increased.

The engine 1 is equipped with a system for recirculating a certain amount of exhaust gases to the inlet side of the engine 1. As mentioned by way of introduction, such an EGR (exhaust gas recirculation) system is already known. According to the invention an additional exhaust gas pipe in the form of an EGR pipe 17 is therefore
15   connected to, for example, the first exhaust gas outlet 8a, that is the outlet which takes exhaust gases from the first cylinder 2a. The EGR pipe 17 is connected to the first exhaust gas outlet 8a via a special EGR valve 18, which preferably consists of an electrically regulated shunt valve. As shown in the figure, the EGR valve 18 is
20   positioned upstream of the turbine 12 and also upstream of the point where the first exhaust gas outlet 8a is connected to the second exhaust gas outlet 8b. In addition the EGR valve 18 is connected to the control unit 6 via an additional electrical connection 19.

25   The control unit 6 is arranged to set the valve 18 in a closed, open or partially open position depending upon the current operating conditions. Dependent upon the state of the valve 18, a corresponding flow of exhaust gases will thus be recirculated to the inlet manifold 3 via the EGR pipe 17. At the same time a corresponding reduction is obtained in the flow of exhaust gases from the first cylinder 2a to the
30   first exhaust gas pipe 9. By means of this recirculating of EGR gases to the inlet manifold 3, a reduction in temperature is achieved during combustion in cylinder 2, whereby the $NO_x$ formation in cylinder 2 is reduced.

To control the valve 18, the control unit 6 is arranged to determine the rotational
35   speed and load (torque) of the engine 1 and to calculate from these parameters the amount of EGR gases required to be recirculated to the inlet manifold. This amount

of EGR gases is mainly determined in the control unit 6 by utilizing a stored table which gives the required amount of EGR gases for optimal reduction of $NO_x$ pollutants as a function of the rotational speed and load. Dependent upon the calculated value for the amount of EGR gas, the valve 18 is then set in a

5    corresponding position by means of a signal from the control unit 6.

The $NO_x$ formation in cylinder 2 is dependent upon the temperature and for this reason it is desirable to reduce to the greatest possible extent the temperature of the gas fed into the engine 1 (which is made up of air and recirculated EGR gases). For

10   this reason the EGR pipe 17 is equipped with a cooler 20 which is designed for cooling the EGR gases recirculated to the inlet manifold 3. For this purpose the cooler 20 comprises a loop 21 through which a suitable cooling medium is passed. This cooling medium consists preferably of the ordinary coolant used in the engine 1, but as an alternative air can be used for this cooling. The EGR gases can be

15   cooled by means of the cooler 21, which further contributes to a reduction in the amount of $NO_x$ pollutants which are created.

Along the inlet pipe 4 there is an intercooler 22 which is used to cool the compressed air which is fed to the engine via the compressor 14. This also

20   contributes to a reduction in the amount of $NO_x$ pollutants which are created in the engine 1. This second cooler 22 is preferably designed for cooling by air, which is indicated diagrammatically by the reference 23.

According to the invention the inlet manifold 3 is designed in a way which aims to

25   provide an even distribution of the recirculated EGR gases to the cylinders 2a-2f. For this purpose the inlet manifold 3 is preferably divided into a first inlet section 3a and a second inlet section 3b which are separated by means of a partition 24. This is shown in the figure, in which the actual inlet manifold 3 is shown in cross section. In addition the EGR pipe 17 is arranged so that it divides downstream of the EGR

30   cooler 20 and goes to a first pipe section 17a and a second pipe section 17b. The first pipe section 17a opens into the first inlet section 3a via a first calibrated opening 25, while the second pipe section 17b opens into the second inlet section 3b via a second calibrated opening 26. The first opening 25 is designed with a first predetermined area $A_1$, while the second opening 26 is designed with a second

35   predetermined area $A_2$.

The first pipe section 17a and the second pipe section 17b open into an EGR mixer 27 which consists of a principally pipe-shaped element which comprises a connection between the inlet manifold 3 and the inlet pipe 4. In this EGR mixer 27 there is a principally homogenous mixing of the charging air fed via the inlet pipe 4

5   and the EGR gases recirculated from the first cylinder 2a and fed through the first pipe section 17a or the second pipe section 17b. For this purpose the EGR mixer 27 is divided in two so that the EGR gases in the first pipe section 17a are mixed with charging air in the inlet pipe 4 separately from the mixing of the EGR gases from the second pipe section 17b with charging air. The mixture of charging air and EGR

10  gases is then fed to the first three cylinders 2a-2c via the first inlet section 3a and to the other three cylinders 2d-2f via the second inlet section 3b.

The term "homogenous mixing" is used here to describe the fact that a homogenous mixing takes place in the EGR mixer 27 principally across the direction of flow of the

15  air. However, there are variations in this mixing during a particular operation cycle along the direction of flow of the air. These variations are due to the exhaust gases being supplied in pulses from the first cylinder 2a while the charging air mainly flows evenly during the said operation cycle.

20  As shown in the figure the partition 24 passes through both the inlet manifold 3 and the EGR mixer 27, that is upstream of the point where the EGR gases are fed into the EGR mixer 27. Consequently, due to the partition 24 there is a division of the flow of gas between the two inlet sections 3a, 3b before it reaches the EGR mixer 27.

25

According to the invention pressure is built up in the first exhaust gas outlet 8a during the operation of the engine 1, which pressure is higher than the pressure on the intake side of the engine 1. In this way a sufficient driving force is obtained for recirculating the EGR gases to the inlet manifold 3, without appreciable reduction in

30  heat balance and without any appreciable deterioration in the efficiency of the engine 1.

A basic principle underlying the invention is that the volume of the inlet manifold 3 and the volumes of the two inlet sections 3a , 3b are calculated in order to provide a

35  principally equally large flow of EGR gases to each of the cylinders 2a-2f. The inlet sections 3a, 3b consist in turn of determined partial volumes which extends between

the branching-off positions defined by the openings 25, 26 for EGR gases and the inlet port (not shown) for each of the cylinders 2a-2f. In particular the volumes of the inlet sections 3a, 3b are determined so that the volumes which are created between the EGR valve 18 and each of the cylinders 2a-2f enable the periodically recurring

5      amounts of EGR gas from the first cylinder to pass along the inlet sections 3a, 3b and be distributed evenly between the cylinders 2a-2f when their respective inlet valves (not shown) are open.

In the figure the reference $V_{EGR}$ refers to the volume which is created between the

10     exhaust gas valve (not shown) of the first cylinder 2a and the openings 25, 26, that is comprising the volume which extends through the valve 18, the pipe 17, the EGR cooler 20 and the pipe sections 17a, 17b. In addition the reference $V_1$ refers to the volume between the EGR mixer 27 and the inlet port of the first cylinder 2a, in particular the volume between a first imaginary plane 28 which extends across the

15     longitudinal direction of the EGR mixer 27, at the opening of the first pipe section 17a, and up to a further imaginary plane 29 which extends across the inlet manifold 3, at the first cylinder 2a. In a corresponding way the volume $V_2$ is defined as the volume between the plane 29 at the first cylinder 2a and the inlet port of the second cylinder 2b, whereby the latter is defined by a further transverse plane 30. In

20     addition the volume $V_3$ is defined as the volume between the plane 30 at the second cylinder 2b and the inlet port of the third cylinder 2c, which is defined by a further plane 31.

The volume $V_4$ is defined as the volume between the EGR mixer 27, that is the

25     plane 28, up to the inlet port of the fourth cylinder 2d, which is defined by a further transverse plane 32. In addition the volume $V_5$ is defined as the volume between the plane 32 and the inlet port of the fifth cylinder 2e, which is defined by a further transverse plane 33.

30     According to the embodiment shown in the figure the first pipe section 17a and the second pipe section 17b are arranged along the same plane, that is along the plane 28. According to an alternative embodiment these two pipe sections 17a, 17b can, however, also open out at different points along the EGR mixer 27.

35     According to the embodiment the partition 24 is designed with an opening 34, that is a connection between the first inlet section 3a and the second inlet section 3b. The

opening 34 is positioned downstream of the third cylinder 2c and is designed with an opening area $A_3$. This opening 34 can reduce pulses in the flow of gas fed through the inlet manifold 3, which would otherwise impair the gas exchange work in the engine 1.

5

According to the invention the dimensions of the respective volumes $V_{EGR}$, $V_1$- $V_5$ are selected so that the flow of EGR gases through the pipe 17 is distributed principally equally between the six cylinders 2a-2f. The size of the opening areas $A_1$-$A_3$ is preferably also selected in a way that contributes to this equal distribution. The

10 EGR gases that are fed through the EGR pipe 17 periodically in the form of pulses of exhaust gas from the first cylinder 2a, are taken past the inlet ports of the six cylinders 2a-2f. By means of the setting of the volumes $V_1$-$V_3$ according to the invention it is ensured that a certain amount of EGR gases is fed in to the first cylinder 2a when the inlet valve (not shown) of the first cylinder 2a is open, that a

15 principally equally large amount is fed in to the second cylinder 2b when the inlet valve (not shown) of the second cylinder 2b is open and that a principally equally large amount is fed into the third cylinder 2c when the inlet valve (not shown) of the third cylinder 2c is open. In a corresponding way by means of the setting of the volumes $V_4$- $V_5$ it is ensured that a principally equally large amount of EGR gases is

20 fed in to the fourth, fifth and sixth cylinder 2d-2f when the inlet valves (not shown) of these cylinders 2d-2f are open.

The design of the said volumes $V_{EGR}$, $V_1$- $V_5$ and the areas $A_1$-$A_3$ can be determined by practical trials or by means of simulations using theoretical models. The flow and

25 the distribution of EGR gases to each of the cylinders 2a-2f is a complex process involving for example the pressure, temperature, speed and composition of the EGR gases in each of the volumes $V_{EGR}$, $V_1$- $V_5$. The settings can therefore suitably be worked out by computer simulation. For such a design an appropriate operating state can be taken as the starting point, for example medium rotational speeds and

30 loads, whereby an even EGR distribution between the cylinders is obtained in normally occurring operating states of the engine. For a standard six-cylinder engine of the diesel type with a compression ratio of the order of 12:1, the said volumes $V_{EGR}$, $V_1$- $V_5$ and the areas $A_1$-$A_3$ are preferably selected as follows:

35 $V_{EGR}$   $V_1$   $V_2$   $V_3$   $V_4$   $V_5$   $A_1$ $A_2$ $A_3$
4.8   2.4   0.8 0.7 4.6 0.9 1.9 2.1 5.0

In the table above the volumes are given in dm3 and the areas in cm². The invention provides an even distribution of EGR gases to the cylinders, which in turn makes possible a considerable reduction in the $NO_x$ emissions from the engine.

The size of the volume extending from the plane 33 up to the inlet of the sixth cylinder 2e is of no great significance, as practically the whole amount of EGR gas which is fed as far as this volume will be drawn in to the sixth cylinder 2e.

The different volumes and areas are set according to a particular operating state which is determined in advance. In those cases where it is desirable to adapt the invention to suit some alternative operating state, other values for the said volumes and areas is of course obtained. According to the invention the volumes and areas can also be set, for example, according to the power of the engine 1 or according to what type of turbo unit 11 is used.

The invention is not restricted to the embodiment described above, but can be varied within the framework of the following claims. For example, the number of cylinders in the engine can vary. In addition the valve 18 can alternatively be of the type that has an on/off setting, that is it can be set only in an open position or a closed position.

In addition the control unit 6 can be arranged to control, for example, the timing of injection for the injection devices 5a-5f in order to further reduce the emission of $NO_x$ pollutants.

The inlet manifold can be divided into two inlet sections with three cylinders each (as shown in the figure) or can alternatively be divided into three inlet sections with two cylinders each, or some other combination which can be selected, for example, depending upon the number of cylinders in the engine for which the invention is used. In addition the inlet manifold can also in principle be designed as a single volume, particularly in engines which have fewer than six cylinders.

In principle any one of the engine's cylinders can be used to supply the EGR gases to be recirculated to the inlet of the engine. In order to make the installation of the EGR pipe and the EGR valve simpler, however, the first or sixth cylinder should

preferably be selected for this purpose (provided that a straight six-cylinder engine is used). In principle EGR gases can also be taken from more than one cylinder.

CLAIMS

1.        System for a combustion engine (1) comprising at least two cylinders (2a-2f), an inlet (3) for the provision of air, an outlet (9, 10) for the emission of exhaust gases, an additional pipe (17) for the recirculating of exhaust gases from at least one cylinder (2a) in the engine (1) to the said inlet (3) for the reduction of harmful emissions from the engine (1), and at least one energy-recovery unit (12) comprising a device (12) for recovering energy from the exhaust gases and also a device (14) for compressing air for the said inlet (3), c h a r a c t e r i z e d   i n  that the said inlet (3) is designed with a volume calculated from the connection (25, 26) of the said pipe (17) to the inlet (3) and up to the inlet port of the respective cylinders (2a-2f), which is so dimensioned that the exhaust gases which are recirculated from the said cylinder (2a) are divided principally equally between the respective cylinders (2a-2f) of the engine (1).

2.        System according to claim 1, c h a r a c t e r i z e d   i n  that the said inlet (3) is divided into at least two inlet sections (3a, 3b) which define partial volumes ($V_5$, $V_2$, $V_3$, $V_4$, $V_5$) for supplying a mixture of air and gases that are recirculated from the said cylinder (2a) to the respective cylinder (2a-2f).

3.        System according to claim 2, c h a r a c t e r i z e d   i n  that a first inlet section (3a) is arranged for supplying a mixture of air and gases that are recirculated from the said cylinder (2a) to a first group of cylinders (2a, 2b, 2c), and that a second inlet section (3b) is arranged for supplying a mixture of air and gases that are recirculated from the said cylinder (2a) to a second group of cylinders (2d, 2e, 2f).

4.        System according to claim 2 or 3, c h a r a c t e r i z e d   i n  that the said inlet sections (3a, 3b) are separated by a partition (24) extending from a point upstream of the point where the gases which are recirculated from the said cylinder (2a) are fed into the said inlet (3).

5.        System according to claim 4, c h a r a c t e r i z e d   i n   that the said partition (24) is designed with an opening (34) for the reduction of pulses in the gas mixture which is fed into the said inlet (3).

6.      System    according    to    any    of    the    preceding    claims,
c h a r a c t e r i z e d   i n   that the said recirculated exhaust gases are taken from
only one cylinder (2a) in the engine (1), whereby a pressure is built up in the said
additional pipe (17) which exceeds the pressure in the said inlet (3).

7.      System according to any of the preceding claims, c h a r a c t e r i z e d
i n  that the said additional pipe (17) is provided with a cooler (20) to cool the
exhaust gases which are recirculated to the said inlet (3).

8.      System according to any of the preceding claims, c h a r a c t e r i z e d
i n  that the said device (12) for recovering energy from the exhaust gases in the
outlet (9, 10) consists of a turbine driven by the exhaust gases.

9.      System according to any of the preceding claims, c h a r a c t e r i z e d
i n  that the pipe (17) includes a controllable valve (18) to adjust the amount of gas
that is recirculated from the said cylinder (2a).

10.     System according to claim 9, c h a r a c t e r i z e d  i n that the said
valve (18) consists of an electrically controlled shunt valve which can be adjusted
continuously between an open and closed position.

11.     System according to claim 9, c h a r a c t e r i z e d  i n  that the said
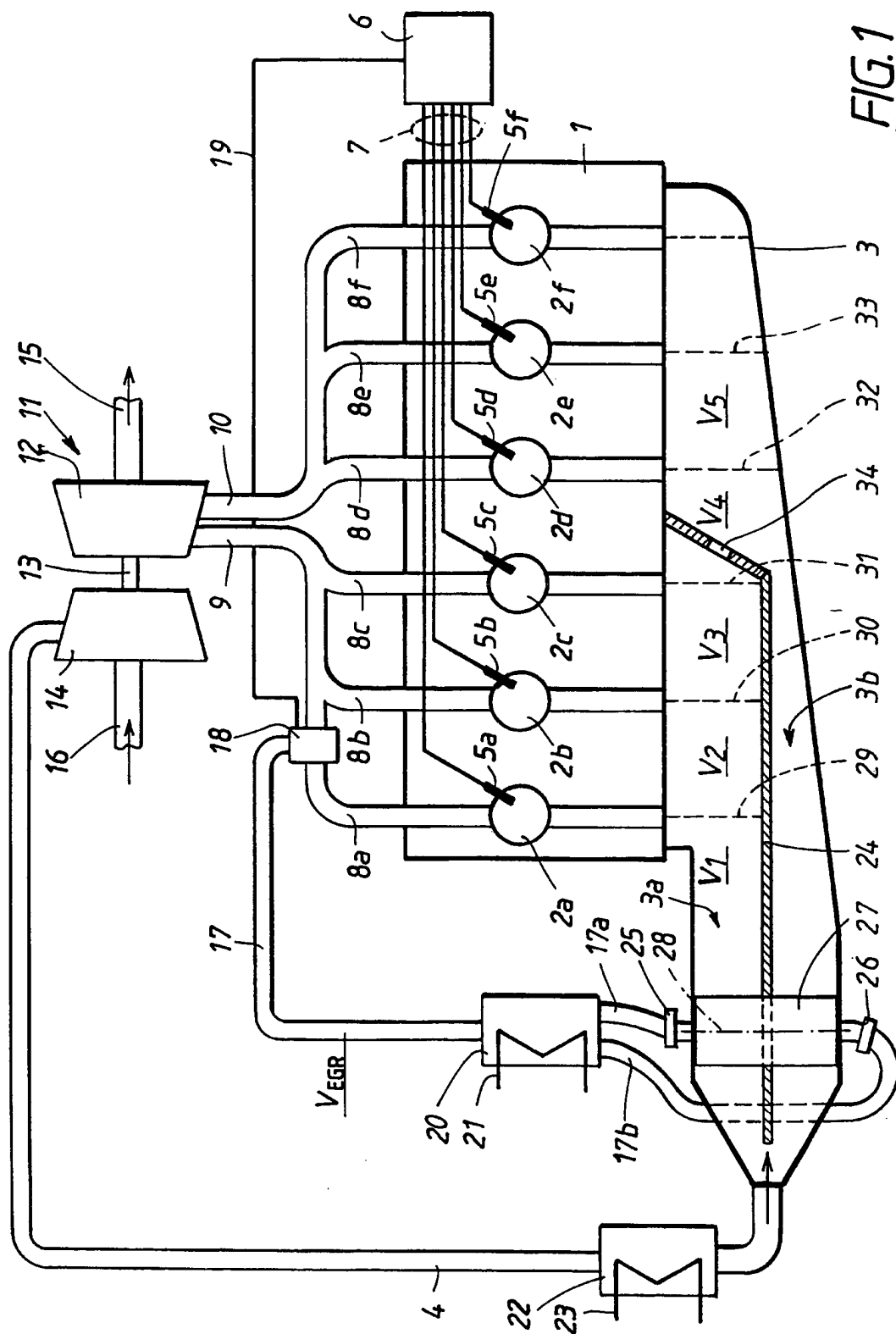valve (18) consists of an on/off valve.

FIG.1

# INTERNATIONAL SEARCH REPORT

| | |
|---|---|
| | International application No. |
| | **PCT/SE 99/00130** |

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F02M 35/104, F02M 25/07, F02B 29/00, F02B 37/00, F02D 21/08

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: F02D, F02M, F02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 4249382 A (EVANS ET AL), 10 February 1981 (10.02.81), figures 1-4, abstract | 1-11 |
| A | US 5611203 A (HENDERSON ET AL), 18 March 1997 (18.03.97), figures 1-2, abstract | |
| A | US 5711154 A (BAECHLE ET AL), 27 January 1998 (27.01.98), figures 1-3, abstract | |

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

| | |
|---|---|
| * Special categories of cited documents: | "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention |
| "A" document defining the general state of the art which is not considered to be of particular relevance | |
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| "P" document published prior to the international filing date but later than the priority date claimed | "&" document member of the same patent family |

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 7 April 1999 | 1 0 -06- 1999 |
| Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86 | Authorized officer Dan Ionesco Telephone No. + 46 8 782 25 00 |

Form PCT/ISA/210 (second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT
Information on patent family members

02/03/99

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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